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20020716 084

Dredging Research

Vol 5, No. 2 Information from the Engineer Research and Development Center Jun. 2002

Disposal facilities shortage generates innovative dredged material management and contaminant flux evaluation solutions

Based on material provided by Drs. Carlos E. Ruiz, Paul R. Schroeder, Michael R. Palermo, U.S. Army Engineer Research and Development Center and Terry K. Gerald, Contract Support

Faced with a lack of disposal facilities for New York/New Jersey harbor's dredged material unsuitable for unrestricted open water placement, the Corps' New York District planning staff turned to engineers and scientists at the Engineer Research and Development Center (ERDC) for solutions. ERDC staff conducted studies to develop technical information based on a feasibility-level evaluation of disposal alternatives and presented findings in a Dredged Material Management Plan (DMMP). In this plan, constructed pits for use as contained aquatic dredged material disposal (CAD) sites are presented as mid- to long-term options (6 or 24 years/pits) within the Lower New York Bay.

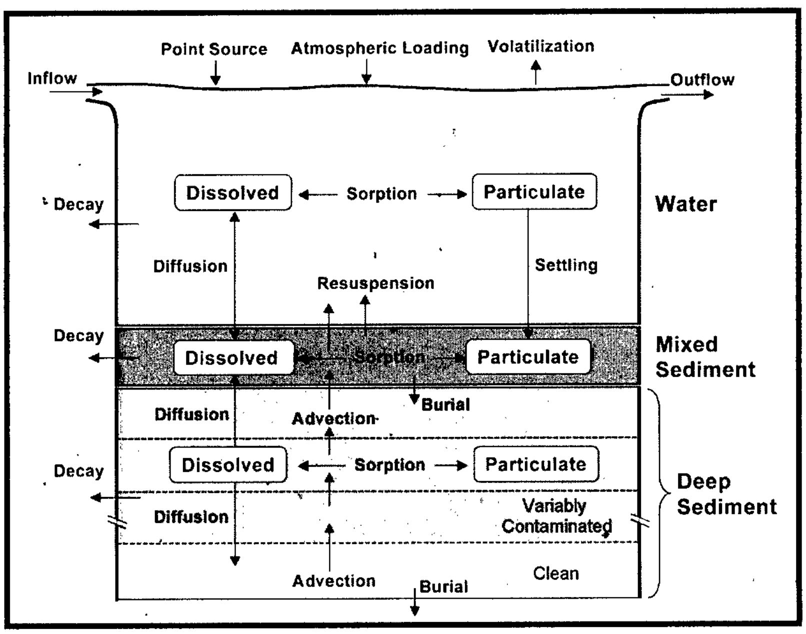

Figure 1. Schematic of CAP Model Processes

Feasibility evaluation for containment of contaminants in the CAD sites was determined by using the Capping Analysis Program (CAP) model.

Plan Summary

The plan calls for a series of small pits, each pit receiving one year's discharge of dredged material. After one year of deposits, the pit will be capped to prevent loss of material and to encourage colonization by benthic organisms and fish. The pit will be capped with material excavated during construction of the new pit. Surficial sediments unsuitable for ocean disposal would be used for capping first. Then these deposits would be capped with clean material from the new pit. The clean sediment caps would also serve to remediate the unsuitable surface sediments, in addition to safely containing the dredged material and returning the area to its previous condition with no long-term loss of habitat or benthic communities.

CAP Model

The Capping Analysis Program (CAP) was developed for use in the

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planning studies for New York CAD facility evaluations. CAP has been developed by ERDC to predict long-term movement of contaminants through caps at CAD sites. The model is an extension of frameworks developed by Corps research staff throughout the past two decades. CAP incorporates a revised version of the USACE RECOVERY sediment-water interaction model and consolidation-induced advection predictions generated from results of the USACE Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill (PSDDF) model. The system is idealized as a well-mixed surface water layer underlain by a vertically stratified sediment column (Fig. 1).

The sediment is assumed to be well mixed horizontally but segmented vertically into a well-mixed surface layer and a deep sediment. The latter, in turn, is segmented into layers of user-defined thickness, properties, and contaminant concentration, which are underlain by an uncontaminated region. The discretized sediment layer configuration is useful for capping scenarios and sites where contamination occurred over a long time; thus, contamination appears layered. The specification of a mixed surface layer is included because an unconsolidated layer is often observed at the surface of sediments due to a number of processes, including bioturbation and mechanical mixing. The contaminant is assumed to follow linear, reversible, equilibrium sorption and first-order decay kinetics. Additional pathways are volatilization, burial, resuspension, settling, advection, and pore-water diffusion.

The advection represents groundwater flow through the sediment profile or expulsion of pore water due to consolidation of the sediment profile. The temporal and spatial advection rates are specified as input.

CAD facility description

DMMP studies have included efforts related to sediment and contaminant reduction. On the basis of this prior research, the projected unsuitable material volume is assumed to decline over time for the CAD pit design.

In sizing the pits, both the depth and area of the pit must be established to provide the required storage volume. To establish the depth, restrictions on storage depth were determined. A maximum excavation depth of 80 ft was assumed since excavation with readily available equipment becomes inefficient and difficult at greater depths. For an ambient 20-ft water depth, the maximum excavated depth was set to be 60 ft below the sediment surface. Pit excavations were designed with 1V:3H side slopes for use in estimating geometries and volumes for excavation and storage.

Limits on the fill height within the pits for unsuitable material (prior to cap placement) are a function of the required cap thickness, the need for placement of surficial material prior to the final cap, and the erosion potential for the unsuitable material. The cap thickness is dependent on the cap design objectives, while the erosion potential is a function of the depth of the unsuitable material surface below the water surface. The cap thickness design must account for components of bioturbation, consolidation, erosion, and operational considerations. Prior experience with cap designs indicated that the potential range of required cap material thickness would be within the range of a few feet. Erosion evaluations determined that a pit could not be filled with unsuitable material to an elevation higher than -30 ft MLW (equivalent to a depth of 10 ft below the lip of the pit for a water depth of 20 ft) without excessive erosion of the unsuitable material due to ambient currents and storm waves. Storage was restricted to elevations between –30 and –80 ft MLW; therefore, the cap thickness was set to be 10 ft. Figure 2 shows a cross section for the 60-ft excavation depth. Sections for more shallow excavation depths would be similar.

The pit areas and dimensions are a function of the required storage volume, the constraints on excavation depths, unsuitable material thicknesses, side slopes, and the aspect ratio (length divided by width). The USACE Short-Term

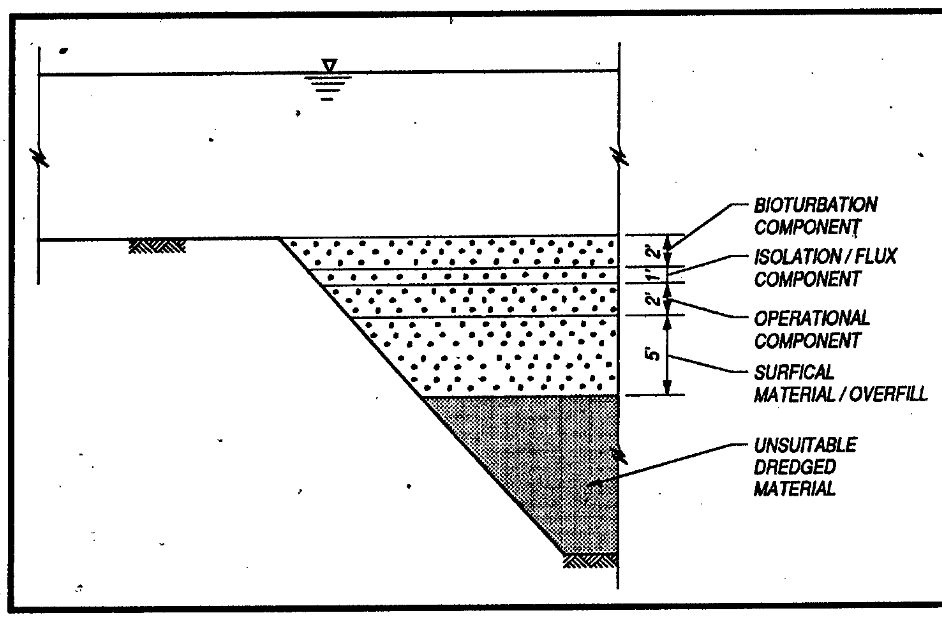

Figure 2. Cross Section of CAD Facility

Table 1
CAD Pit Areas, Excavated Depths, and Excavated Volumes

Unsuitable Material Capacity million cy	Surface Width ft	Surface Length ft	Surface Area acres	Excavated Depth ft	Excavated Volume million cy
2.25	700	2,800	44	60	2.91
1.75	700	2,200	35	60	2.27
1.25	700	2,200	35	40	1.80
0.75	700	2,200	35	27	1.32

FATE (STFATE) model determined that a minimum pit width of 700 ft was optimal for planning the final pit areas and dimensions. Based on sizing calculations, a minimum 2,200-ft pit length was selected for best retention efficiency. The recommended size of the CAD pits for an annual dredging requirement of 2.25 million cubic yards is 700 by 2,800 ft (approximately 44 acres) with an excavated depth of 60 ft. A cluster of six pit cells of this size is needed to meet the mid-term requirement. The required size of the pits declines over time for the 24-year long-term option. The dimensions and geometries of the pits are summarized in Table 1.

Study overview

A number of proposed CAD facilities in 20 ft of water were considered, ranging from 40 to 60 acres in area, 40 to 60 ft of dredged material, and 3 to 10 ft of capping thickness. Results of the studies for the proposed pit caps for NY harbor indicated that the contaminated sediment layer would consolidate to roughly half of its initial thickness over a period of decades. The NY harbor sediments contain a number of contaminants. Copper was determined to be the contaminant of concern (COC) for its potential water quality impact based on its concentration, ability to partition to the water phase, and the magnitude of its water quality standard. CAP was run to predict the contaminant fate at the CAD site and in the surrounding ambient sediment to compare the contaminant flux from the pits to that of the ambient sediments. Water and copper were predicted to move through the cap due to consolidation-induced advection. The simulations show that fluxes from the dredged material peak shortly after the initial consolidation and decrease thereafter. The ambient sediment at the CAD site has an elevated copper concentration, but it is only one fifth of the copper concentration of the dredged material to be placed in the CAD facility. Long-term simulations for the background and the proposed CAD pit show less total flux from the pit than from the background.

Results

The predicted consolidation-induced water advection results are shown in Figure 3 for the 60-ft pit under two different foundation conditions (drained and undrained).

The singly drained condition is characteristic of a fine-grained material at the base of the excavation, which does not permit significant drainage through the base of the pit. Therefore, water is expelled only upward from the consolidating material. The doubly drained condition is characteristic of a coarse-grained material at the base of the excavation, which permits drainage of expelled water downward as well as upward.

The ultimate total settlement is the same for the singly and doubly drained condition, but the settlement is nearly twice as fast initially if doubly drained. However, the initial/maximum upward fluxes of expelled water are similar for the two conditions (about 2 ft/year), but the average flux in the first year is about 20 percent less for the doubly drained condition. The total volume of water expelled upward from the dredged material in a doubly drained condition is reduced by about 40 percent since that fraction is drained downward.

After the first year or two, the flux in all cases gradually decreases from about 8 in./year to about 4 in./year over a period of 25 to 30 years. After 30 years the flux slows and is dependent on the design and foundation conditions. Consolidation would be completed in 50 to 100 years if doubly drained and in 100 to 200 years if singly drained.

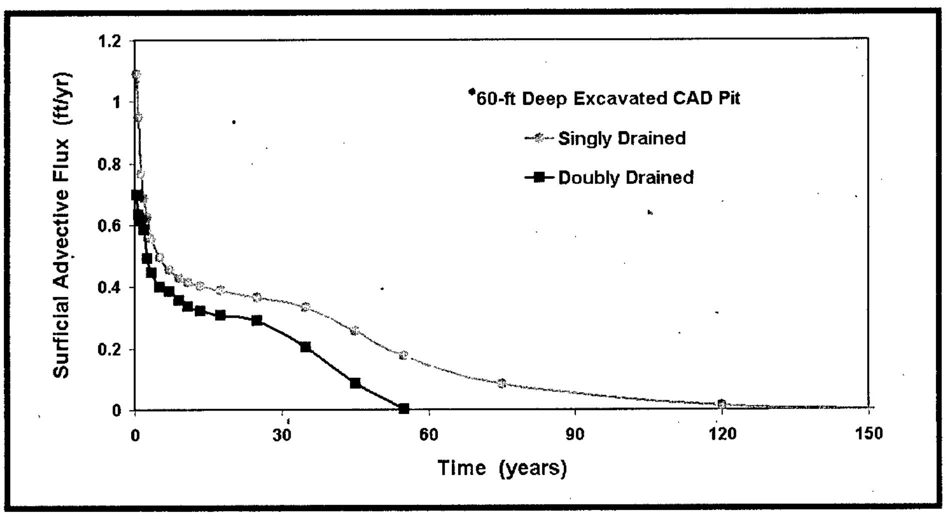

Figure 3. Water flux predictions for 60-ft deep CAD pit

Contaminant fluxes associated with the advection of water resulting from dredged material consolidation were estimated for the singly drained 60-ft CAD facility. The singly drained CAD pit will expel water only upward, thus having the potential for greater contaminant flux. Figures 4 and 5 show the predicted copper concentration in the surficial sediments and the predicted total copper flux associated with the dredged material consolidation (water advection) and diffusion across the sediment water interface. The background diffusion results in these figures refer to the results of copper diffusion from the sediment bottom (without advection) currently at New York's Lower Bay.

Clean cap diffusion refers to the results of copper diffusion in the absence of consolidation and pore water advection through the "clean" material used for capping the CAD facility. Some of the copper from the lower layer of the cap, but none from the dredged material, was transported to the surface during the period of advection. Results show that the surficial copper concentration in the background sediments is expected to be three- to four-times greater than in the CAD facility during the 250-year simulation period. Similarly, the flux of copper to the water column from the background sediment was predicted to be about twice as great as from the CAD facility. As such, the CAD facility is predicted to improve long-term water quality.

Predictions of the concentration and flux of copper for diffusion from the clean CAD cap material (in the absence of consolidation and advection of pore water) were compared with those for the singly drained CAD facility to provide information on the relative importance of consolidation/advection and diffusion on the performance of a cap. The flux due to consolidation/advection was about three to five times that of diffusion over the first 30 years when consolidation was pronounced and nearly steady.

Conclusions

The 5-ft clean cap of the CAD facility is predicted to be an effective isolation layer for the 50-ft layer of highly compressible dredged material that was unsuitable for open water disposal due to its contamination with copper and other contaminants of lesser concern. While consolidation induces contaminant transport from the dredged material at a rate of as much as five times greater than diffusion, the cap materials are able to retard the progress of the contaminants throughout the consolidation period. The "clean" CAD cap is predicted to be cleaner than the background sediments throughout the life of the facility.

The CAP model, developed specifically for this project, was demonstrated to be an excellent tool for evaluating CAD facilities. The model allows cap designers to assess the impact of consolidation on contaminant transport, to determine optimal isolation thickness, and to select materials to manage the contaminant containment.

More information can be obtained by contacting the research staff of the Environmental Laboratory, ERCD: Carlos Ruiz, research civil engineer, *Carlos.E.Ruiz@erdc. usace.army.mil*; Paul Schroeder, research civil engineer, *Paul.R.Schroeder@ erdc.usace.army.mil*; Mike Palermo, Director, Center for Contaminated Sediments, *Michael.R.Palermo@erdc.usace.army.mil*; and Terry K. Gerald, senior researcher, ASI, *Terry.K. Gerald@erdc.usace.army.mil*.

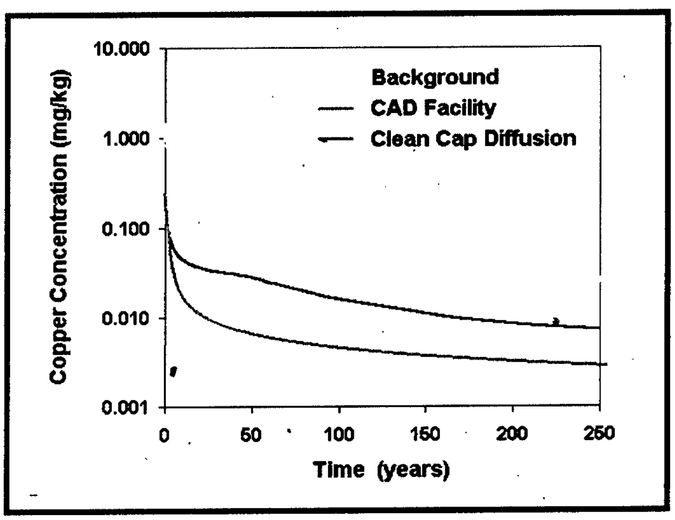

Figure 4. Predicted mixed layer copper concentrations

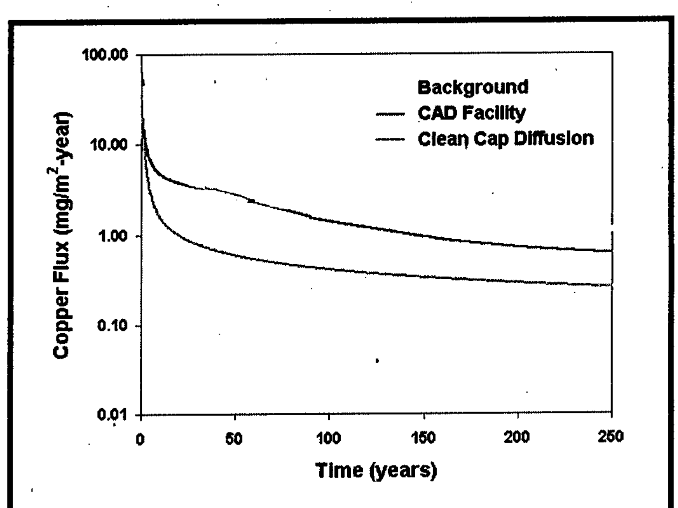

Figure 5. Total copper flux to the water column from surficial sediments

Upland Testing Manual in final stages of development — to contain tiered evaluations for CDF contaminant pathways

by Dr. Michael R. Palermo, U.S. Army Engineer Research and Development Center, Environmental Laboratory

The U.S. Army Corps of Engineers conducts dredging operations for the Federal navigation program and, jointly with the EPA, regulates dredging activities under both the Marine Protection Research and Sanctuaries Act (MPRSA) and Clean Water Act (CWA). USACE and EPA have long recognized the need for consistency in decision-making regarding alternatives for dredged material management, and the agencies jointly developed a Technical Framework describing the approaches for identifying the environmental effects of dredged material management alternatives (including the potential for contaminant-related impacts). A series of detailed guidance documents support the Technical Framework. For example, the Ocean Testing Manual (OTM) and Inland Testing Manual (ITM) provide detailed procedures for evaluating the suitability of dredged material for disposal at open water sites, focusing on potential contaminant-related water column and benthic effects. The USACE has now developed the manual *Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore or Upland Confined Disposal Facilities - Testing Manual*, commonly called the Upland Testing Manual, providing technical guidance for evaluation of potential contaminant migration pathways from confined disposal facilities. The UTM, like the OTM and ITM, is consistent with and supports the Technical Framework by providing detailed procedures for assessment of contaminant-related impacts.

CDF Contaminant Pathways

Confined disposal facilities (CDFs) are one of the most widely used options for placement of contaminated sediments. Contaminant migration pathways are routes by which contaminants or constituents of concern associated with dredged material may move from the dredged material within the site into the environment outside the site.

The possible pathways from an upland CDF are illustrated in Figure 1: 1) effluent discharges to surface water during filling operations and subsequent settling and dewatering, 2) precipitation surface runoff, 3) leachate into groundwater, 4) volatilization to the atmosphere, 5) direct uptake by animals, and 6) direct uptake by plants, with subsequent cycling from animals and plants through food webs. Pathways for nearshore or island CDFs would be similar to upland sites. That portion of a nearshore or island CDF raised above the mean high-water elevation will essentially function as an upland CDF.

If contaminated sediments are placed in a CDF, pathways for migration of contaminants from the site and potential contaminant impacts should be evaluated. A suite of evaluation procedures and laboratory test procedures has been developed to evaluate CDF contaminant pathways and are presented in detail in the UTM. Some of these procedures and tests have been field verified and are now in general use, while others are newly developed and field verification is underway or planned.

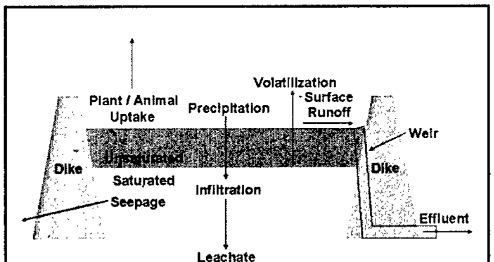

Figure 1. Schematic of contaminant migration pathways for upland CDFs

UTM purpose and applicability

The purpose of the UTM is to provide technical guidance for evaluation, where appropriate, of potential contaminant migration pathways for proposed disposal of dredged material in CDFs. Procedures in the UTM will

- Determine potential contaminant releases and contaminant-related environmental effects from CDFs, and
- Determine whether pathway-specific contaminant controls or management actions are necessary for the proposed CDF to avoid unacceptable adverse effects outside the site.

The focus of the UTM differs from that of the OTM or ITM, both of which determine the suitability of a proposed dredged material for placement at an open water site. The UTM is intended as a *resource* of technical guidance for use by the USACE, Federal and State regulatory and resource agencies, dredging permit applicants, and others (e.g., scientists and engineers, managers, and other involved or concerned individuals). It is intended to facilitate decision-making with regard to the management of dredged material. Because the UTM is national in scope, the guidance provided is generic and may be applied within various regulatory settings, but does not alter the statutory and regulatory framework for permitting decisions under any applicable laws or regulations.

Tier	Contaminant Migration Pathways For CDFs					
	Effluent	Runoff	Leachate	Volatilization	Plant Uptake	Animal Uptake
I	Existing information	Existing information	Existing information	Existing information	Existing information, conceptual site model, complete exposure routes	Existing information, conceptual site model, complete exposure routes
II	Total release screen and/or solubility partitioning screen	Solubility partitioning screen	Solubility partitioning screen	Volatility partitioning screen	DTPA extract, COC elimination	TBP calculation, COC elimination
III	LTCST turbidity/ TSS EET chemistry EET toxicity	SLRP and/or RSLS chemistry SLRP and/or RSLS toxicity	SBLT chemistry and/or PCLT chemistry	VFC chemistry	Plant bioaccumulation test	Animal bioaccumulation test
IV	Case specific study or risk assessment	Case specific study or risk assessment	Case specific study or risk assessment	Case specific study or risk assessment	Case specific study or risk assessment	Case specific study or risk assessment

EET = Effluent Elutriate Test; SLRP = Simplified Laboratory Runoff Procedure; RSLS = Rainfall Simulator/ Lysimeter System; SBLT = Sequential Batch Leachate Procedure; PCLT = Pancake Column Leach Test; VFC = Volatile Flux Chamber; DTPA = Diethylenetriamine- pentaacetic acid; TBP = Theoretical Bioaccumulation Procedure; LTCST = Long Tube Column Settling Test

Figure 2. Summary of evaluation structure and procedures in UTM

Tiered structure

The UTM uses a four-tiered evaluation process for each of the five pathways. This approach should be initiated at Tier I for each pathway, and is designed to aid in generating appropriate and sufficient, but not more than necessary, information to make decisions regarding the need for management actions. This allows optimal use of resources by

- Focusing the least effort on projects where the potential need (or lack thereof) for management actions is clear.
- Maximizing effort on operations needing extensive investigation to determine the level of management actions.

The tiered framework is used independently for each pathway of concern. Process through the tiers stops when information is sufficient to make a decision about the pathway under evaluation. For example, if the available information is sufficient to make a decision in Tier I about surface runoff, no further evaluation of surface runoff is required. The evaluation would then shift to the next pathway, which might have to be carried through Tier III to generate sufficient information to make a decision.

At the outset of a typical evaluation of a particular pathway, it may be possible to conduct evaluations in general terms. Evaluation at successive tiers involves more extensive and specific information about the potential need for management actions. Successive tiers may involve more time-consuming and expensive procedures, but provide more extensive information allowing more detailed evaluations of the need for management actions. Evaluation in progressively higher tiers should be conducted *only* if the information at a given tier is not sufficient to make a decision regarding the need for management actions.

The tiered structure for each pathway, illustrated in matrix form in Figure 2, includes the types of evaluations and specific pathway tests. Many of the tests and models described in the UTM have been available for some time, but the detailed procedures for conducting the pathway evaluations within the tiered framework are all new.

For example, Tier I uses readily available existing information. The Tier I evaluation should determine the need for evaluation of pathways (comparable to the exemptions from testing and "reason to believe" concepts in the OTM and ITM), identify the pathways (if any) that should be evaluated further and identify receptors of concern and contaminants of concern (if any) for further evaluation.

If a decision for a given pathway cannot be made at Tier I, Tier II evaluations consist of determining the need for management actions derived from very conservative techniques that use the chemical, physical and biological characteristics of the dredged material and basic information about the CDF. Tier II includes screening evaluations based on contaminant partitioning principles and screening level tests to evaluate the need for management actions to meet applicable water quality standards, groundwater standards, etc. These screening procedures have been programmed using electronic spreadsheets, and the spreadsheets will be included with the UTM.

The evaluations in Tier III are generally more complex, costly, data intensive and time-consuming than those in the previous tiers. Tier III includes the contaminant pathway laboratory tests which have been available for some time. Figure 2 provides the names of the various pathway tests incorporated in the UTM. These tests were initially developed under the USACE Long Term Effects of Dredging Operations (LEDO) research program and other related research and project-specific studies. Some of the procedures were field verified under the joint USACE/EPA Field Verification Program (FVP), and others are now and will be field verified under the ongoing Dredging Operations and Environmental Research (DOER) program.

The procedures in Tiers I through III are risk-based, and the data generated directly supports either an exposure or effects assessment. Tier IV in the UTM consists of case-specific studies or formal quantitative risk assessment designed to answer specific, well-defined questions, and should rarely be necessary for navigation projects. This risk guidance will be especially

applicable for evaluation of the plant and animal uptake pathways for those CDFs requiring a formalized risk assessment.

Management actions

If a decision is made that management actions are needed for a given pathway, the influence of the management actions on other pathways should be considered. For example, the placement of a surface cover of clean material to control surface runoff will also control plant or animal bioaccumulation. Consideration of such influences may allow for a reduction in testing efforts or the need to re-evaluate some pathways. The full evaluation of all pathways may therefore be an iterative process, depending on the project requirements. The UTM does not provide guidance for selecting, designing or implementing any needed CDF controls or management actions. This information is published in various USACE engineer manuals and other publications.

Publication and updates

The UTM is currently undergoing review by the USACE and EPA. Once revisions based on this review are incorporated, the manual will be published on the USACE Dredging Operations Technical Support (DOTS) Web site at *www.wes.army.mil/el/dots* where the manual may be read on-line, downloaded or printed (no hardcopy publication is planned). Updates and revisions to the UTM will be made as additional research is completed and field experience is gained. Users are encouraged to obtain the most recent version of the manual, which will be maintained on the DOTS Web site.

Additional information is available by contacting Michael Palermo at *Michael.R.Palermo@erdc.usace.army.mil.*

Dredging Calendar

2002

July 9-11 - EPA and U.S. Army Corps of Engineers, Dredged Material Assessment and Management Seminar, Crowne Plaza Union Square, San Francisco, CA. **POC:** online, *www.wes.army.mil/el/dots/training.html*, FAX 601-634-3528, e-mail *Billie.H.Skinner@erdc.usace.army.mil*

May 1, but no later than August 1 - TRB call for papers on any transportation-related subject For 82nd Annual Meeting. Papers cannot be accepted after August 1, 2002, because of the time required for peer review and program development. The paper submission requirements are posted at *http://www4.nas.edu/trb/annual.nsf/web/Calls_for_Papers* Papers are welcome from U.S. and international authors. See meeting notes below for 2003.

September 13 - **Call for papers:** Inaugural National Conference on Coastal and Estuarine Habitat Restoration, 2003, see information below. Proposals will be accepted for interactive workshops, facilitated discussions, panel presentations, lectures and outdoor learning opportunities of 90 minute or less. Subjects are: *Best Practices in Restoration; Community Involvement; Planning and Priority-Setting; Science and Technology; Monitoring and Evaluation; Policy and Funding*. Acceptance notice will be issued in November.

September 22-27 - American Association of Port Authorities Annual Convention, Palm Beach, FL. **POC:** *www.aapa2002.com*

September 22-26 - PIANC 30th International Navigation Congress, Sydney, Australia. **POC:** *http://www.pianc-aipcn.org/pi200.html*, e-mail: *pianc2002@tourhosts.com.au*

October 16-18 - 5th International Symposium on Sediment Quality Assessment, 2002. Hotel Allegro, Chicago, IL, USA. **POC:** *http://www.aehms.org* or write to the Conference treasurer before July 31, 2002 to: AEHMS, 365 Wildwood Prk., Winnipeg, MB, Canada, R3T 0E7; E-mail: *jchase@aehms.org*

November 16-22 - SETAC (Society of Environmental Toxicology and Chemistry) North America 23rd Annual Meeting, Salt Lake City, UT. *Achieving Global Environmental Quality: Integrating Science & Management.* **POC:** *www.setac.org/meet.html*

2003

January 12-16 - TRB 82d Annual Meeting 2003,The Marriot Wardman Park, Omni Shoreham, and Hilton Washington hotels in Washington, DC, host more than 450 formal sessions and 300+ committee meetings. More than 8,500 transportation professionals from the United States and abroad are expected to attend. More information can be found at: *http://www4.nas.edu/trb/annual.nsf/web/homepage?OpenDocument*

April 13-16 - Inaugural National Conference on Coastal and Estuarine Habitat Restoration, Baltimore, MD, Hyatt Regency Inner Harbor. The conference is the first nationwide forum focused solely on the goals and practices of coastal and estuarine habitat restoration. **POC:** Rick Bates, Development Director at Restore America's Estuaries, at (703) 524-0248, e-mail *rickbates@estuaries.org*

May 26-28 - 2d International Symposium on Contaminated Sediments. Loews Le Concorde Hotel, Quebec City, Canada. Sponsors: ASTM, CGS, CSCE, SRA-SETAC. **POC** and information can be found at: *http://www.scs2003.ggl.ulaval.ca/SCS2003_English.pdf*

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Articles from non-ERDC authors are solicited for publication, especially if the work described is tied to the use of ERDC-generated research results. Research articles that complement ERDC research or cover wide field applications are also accepted for consideration. Manuscripts should use a nontechnical writing style and should include suggestions for visuals and an author point of contact. Point of contact is Elke Briuer, APR, at *Elke.Briuer@erdc.usace.army.mil.*

Dredging Research

This bulletin is published in accordance with AR 25-30 as an information dissemination function of the Environmental Laboratory of the U.S. Army Engineer Research and Development Center. The publication is part of the technology transfer mission of the Dredging Operations Technical Support (DOTS) Program and includes information about various dredging research areas. Special emphasis will be placed on articles relating to application of research results or technology to specific project needs. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or the approval of the use of such commercial products. Contributions are solicited from all sources and will be considered for publication. Editor is Elke Briuer, APR, *Elke.Briuer@erdc.usace.army.mil.* Mail correspondence to the Environmental Laboratory, ATTN: DOTS, Dredging Research, U.S. Army Engineer Research and Development Center, Waterways Experiment Station (CEERD-EP-D), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or call (601) 634-2349. Internet address: *www.wes.army.mil/el/dots/drieb.html.*

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